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How to generate evidence for the emergence of new psychological forms: *Grundlegung der Psychologie* and its contribution to method

Wolff-Michael Roth

Abstract
One of the important, but perhaps less appreciated, contributions of the *Grundlegung der Psychologie* is the articulation of a method suited to provide evidence for the emergence and dominance of qualitatively new psychological functions and behaviors. The method is grounded in materialist dialectics generally and the laws of (a) the transformation of quantity into quality (and vice versa) and (b) the interpenetration of opposites, specifically. The purpose of this article is to present the methodical precept, which may be unknown in the English-speaking world in the context of the description of (a) relevant and interesting psychological phenomena encountered by educators on a daily basis and (b) a catastrophe-theoretical (mathematical) approach for classifying morphogenetic events in the natural sciences, social sciences, and humanities. The discussion is concerned with highlighting some important theoretical and empirical issues.

Keywords
dialectical materialism, dialectical laws, quantity, quality, psychological functions, development vs. learning

In the opening section of *Grundlegung der Psychologie*, Klaus Holzkamp (1983) notes that one of the special contributions of *Kritische Psychologie* is its method, which is designed to establish a categorical basis for psychology that has paradigmatic character. Grounded in materialist dialectics, the method is adequate for working out the development of new dominant psychological

functions on the basis of, and overturning, previously dominant functions. The method is part of a project of providing psychology with a scientifically founded, categorical basis. Despite the important role that method plays in the *Grundlegung*, many studies under the influence of (social) constructivism do not attend to the requirements that psychological functions have to be plausible on cultural-historical grounds. Researchers therefore have to show accounts that attempt to show how qualitatively new psychological functions emerge on the grounds of old functions, which are sublated while the new psychological functions become dominant. The method can be traced historically from G. Hegel to F. Engels' statement of the law of the transition of quantity into quality, a statement that was taken up directly in the social psychology of L. S. Vygotsky (1997a), who exhorted psychologists to write their own *Das Kapital*. The purpose of this contribution is to exhibit the methodical precepts of the *Grundlegung* in the context of two concrete vignettes where developmental phenomena are apparent. I begin by describing the two cases and then articulate basic principles of catastrophe theory, which constitutes a discourse and method that combines quantitative and qualitative reasoning into a system that can be used to classify morphogenetic phenomena, that is, phenomena where qualitatively new forms arise. I then articulate the five steps that a dialectical materialist account of the emergence of new psychological functions requires consistent with the methodical approach of the *Grundlegung*, steps that should be heeded by every qualitatively working researcher. This method of describing the emergence of new forms (morphogenesis) turns out to be a special (psychological) case within a more general catastrophe-theoretic discourse. I conclude by pointing out a specific lacuna in Holzkamp's formulation, elaborate on the differences between a Hegelian and Spinozist Marxian approach to the study of psychological phenomena, and consider some implications for differentiating learning and development, the latter of which may be studied under the aegis of the zone of proximal development.

Quantitative and qualitative changes in psychological phenomena

In this section, I present two case studies in which the emergence of qualitatively new phenomena has been observed. The cases serve as the empirical backdrop and material for establishing the conceptual and methodical precepts for the study of morphogenetic phenomena, defined as phenomena in which quantitative variation leads to leaps to qualitatively new features.

Case 1: Reasoning on the balance beam

As part of a design experiment on teaching a unit on simple machines to 11–12-year-old elementary school students (6th and 7th grade), we interviewed students prior to beginning the unit. The interviews involved questions about equilibrating a balance beam. Given a weight hanging at a particular distance from the fulcrum, students were asked where a second, different weight should be hung on the opposite side to bring the beam into balance. The interviewer creates a balanced beam by placing 2-unit weights at 2-unit distances on each side of the device. The interviewer then holds the beam, removes one of the unit weights on the left side of the beam and asks the student (Aslam) where to place the remaining 1-unit weight to make the beam balanced (Figure 1.a). Aslam suggests moving the weight by one distance unit to the 3-unit distance from the fulcrum. He explains that because 2 weight units plus 2 distance units yields 4, which is the same that is obtained when a 1-unit weight is placed at a 3-unit distance. After another task of the same kind, the interviewer turns the balance beam around where there are no distance marks. He places the 2-unit weight at a certain distance and then asks Aslam where the 1-unit weight should be placed on the opposite side of the beam (Figure 1.b). The student suggests that because the 1-unit weight is only one half of the other, it should be placed twice as far ("because you doubled the weight"). The interviewer turns the beam around again, places a 2-unit weight at a 6-unit distance and asks, where to hang the 3-unit weight. Aslam suggests where the beam reads "4," and, when asked, says, "You do three times that" while pointing to the 4-unit distance. He then suggests, "take away one-third" because the weight on the other side is "one-third less."

In this situation, we observe an example of reasoning on the balance beam that Inhelder and Piaget (1958) theorized to be Level II-B in his developmental scheme, additive reasoning at the concrete operational level. In the second part of the session, Aslam was using both a multiplicative and a ratio scheme, the latter constituting reasoning at level III-A (formal operations) in Piaget's developmental stage theory. In this theory, such developmental changes are the result of biological processes, including that of *accommodation* and *assimilation*. Whenever an existing (mental) schema is appropriate, new situations can be understood in terms of it and assimilated into a person's set of experiences. When existing schemas are inappropriate, a conceptual reorganization may occur, an accommodation, such that the new situation can be assimilated to the newly created schema. Although the new schema clearly is qualitatively different, it appears to be another schema that increases the totality of schemas available to the person. Biologically, then, development has been reduced to a series of quantitative changes.

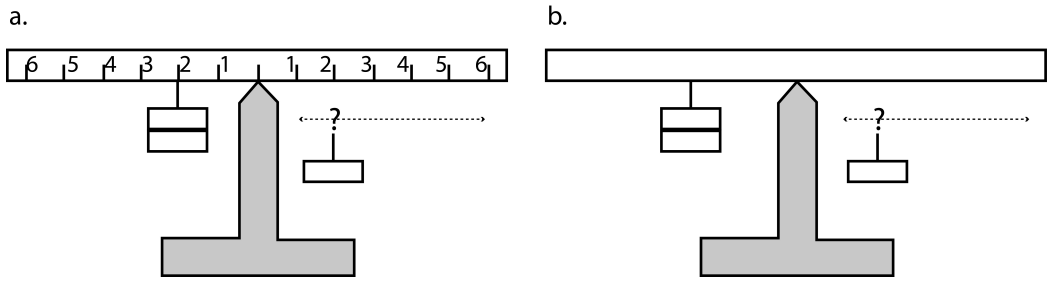

Figure 1. Two conditions for the balance beam task. a. The beam has equidistant markers and numbers. b. The beam has no markers.

The two processes may be understood as quantitative and qualitative changes in the historical trajectory of the person. Thus, assimilation is simply an accretion of a new situation and forms of knowledge to an existing class of experiences. Accommodation creates a qualitatively new class with the current experience as its first member. Thus, in the case of Aslam, Piagetian researchers might have described the observation as the spontaneous creation of the multiplicative and ratio schemes of reasoning, corresponding to the qualitative turnover from the concrete operational stage II-B to the formal operational stage III-A. Subsequent work within this paradigm formalized such changes in terms of the person's information processing capacities. In one theory, development was theorized in terms of the mental short-term memory capacity thought to increase from 0 to about 8 or 9 units (Pascual-Leone, 1970). In this approach, changes are incremental, therefore quantitative, and the qualitative aspect of the stage-wise developmental theory had disappeared. In another theory, the stage-wise aspect was retained to explain the qualitative changes in behavior, whereas changes within a stage were theorized in terms of quantitative accretion of (mental) short-term storage space (Case, 1985). In all three approaches, development is treated in terms of the "maturation of the nervous system" (Inhelder & Piaget, 1958: 337), though these authors recognize that "the nervous system can do no more than determine the totality of possibilities and impossibilities at a given stage" (337). The physical and social environment has the function of accelerating or retarding the maturation rate.

A very different approach is taken in cultural-historical psychology, which adheres to the Marxian principle that "the essence of man … is the ensemble of societal relations" (Marx & Engels, 1978: 6). Thus, whereas human life certainly is a manifestation of biology, societal relations (culture) are the origin of what makes humans different from other animals (Vygotsky, 1997b). Therefore, qualitative changes in human behavior are not merely biological, though

necessarily enabled by them. Instead, when a person—in Vygotsky's discussion, virtually always children generally accompanied by teachers or more capable peers—engages in *joint* labor (behavior) with another person, then that relation may later show up as the individual labor (behavior). Thus, when Vygotsky writes about the growth of logical memory, he points out that there are not only quantitative changes, but also qualitative changes of the function of remembering in terms of "its composition, structure, and method of action" (Vygotsky, 1998: 98). The joint labor provides for a *zone of proximal development*, where qualitatively new forms of acting arise out of participation in some task. Participation in the relation and individual contributions to joint actions necessarily are at the person's current developmental levels; but that participation provides for a changeover to a qualitatively new level. Importantly, whereas changes prior to the developmental change were incremental, development itself is characterized as a qualitative change, a transition between qualitatively different forms of behavior. Thus, following the changeover, subsequent incremental change will take a very different form from that which had taken place prior to the qualitative leap. It is therefore important to differentiate between cumulative, quantitative change within a form of behavior and transformative and revolutionary change that leads from a first to a second, qualitatively different form of behavior.

Case 2: Revolution of teaching

A well-researched area of change is referred to as "professional development." However, in the different disciplinary literatures—teaching, nursing, flying an aircraft, doing one's everyday business—the term is used independently of the question whether the observed changes in behavior or consciousness are cumulative or transformative (e.g., Jóhannsdóttir & Roth, 2014). Even though biological (maturation) processes are less important in adults—though they are important later in life when certain physical and physiological capacities decline—there are phenomena that correspond to qualitative changeovers (e.g. in consciousness) and subsequent cumulative changes that substantially differ from those that had occurred prior to the transformation. Take the following story of a teacher named Leandro that I was told by a Brazilian doctoral student of mine.

Leandro had begun teaching in a private school while being enrolled in a teacher education program. The purpose of the school was to prepare students for the compulsory college entrance examinations. He designed his lessons as self-contained units, with little connections between consecutive units. Over his years of teaching, which later continued in the public school system, he incrementally

improved his presentation style by refining the materials and his ways of interacting with students. It was out of this context of teaching social studies at a secondary school that he agreed to be a participant in a research project. With another teacher from his school and the doctoral student conducting the study, he discussed issues of teaching and a variety of readings. One of these discussions became the context of a radical change in consciousness, which entailed qualitative changes in the ways Leandro was conceiving teaching, preparing curriculum and lesson plans, and in the ways in which he actually taught. His growth trajectory changed from what it was before, ultimately leading him back to university to enroll in a graduate program to do a Masters degree and later begin doctoral studies.

The discussion where the radical transformation began had a journal article as its topic. The article presented the account of the experience of a teacher, who had used a Freire-inspired problem-based approach. Under the motto "Poop on the Beach? No!," local citizens rallied against the government project of building an outfall releasing raw sewage into the ocean just off a poor neighborhood (Saito, 1999). The teacher created the opportunity for students to participate in this popular movement, which led them to develop critical consciousness and participate in the collective action against the project.

Leandro emerged deeply disturbed from reading the article. The discussion with other members of the research group deepened his unease, which he formulated in terms of the problem that what he had been doing—though always with the well-being of his students in mind—has nothing to do with students' interests and was not helping them to become (critical) citizens. In this and subsequent discussions, the members of the research group were thinking about different ways of teaching, leading to the development of a first set of lessons in which Leandro would be addressing students' needs and relevance to their lives. He changed from the teacher-directed style that characterized his teaching before to a new form of teaching that fostered classroom dialogue. Rather than planning the entire curriculum at the beginning of the school year, his planning became adaptive so that the lesson content and structure would take into account the specific student needs that emerged during the lived curriculum itself. In the process, Leandro underwent a developmental process of consciousness not only pertaining to his own ways of being, but also for the social conditions that reproduce the very phenomena (student failure, unemployment) that these same conditions are supposedly designed to overcome. It was a process known as *conscientização*, which consists of and allows for the critical consciousness of societal (political) contradictions; and out of this process, he was able to engage students in ways to foster *conscientização* in them.

In this instance, there are roughly two periods of cumulative changes; but these looked very different. The two periods of cumulative professional growth were separated by a qualitative changeover, which had led to a new form of consciousness and associated changes in the ways in which Leandro thought about teaching and actually taught. Vygotsky articulates consciousness as *perežívanie* [experience] of *perežívanie*. Near the end of his life, he defined *perežívanie* in terms of a person–environment unity/identity, that is, as a person-acting-in-environment system, where the environment is understood in terms of what appears to the person in consciousness (as opposed to the objective environment studied by the natural sciences). To capture this irreducible unity/identity in one term, we may write {person | environment} with the understanding that each of the two terms is a manifestation of the same whole. Although Vygotsky is interested in the processes by means of which emerges "a qualitatively unique form, truly new from that which appears in the developmental process" (Vygotsky, 1997b: 72), he does not actually articulate what investigators have to do to provide necessary and sufficient evidence for the qualitatively new forms of behavior.

Catastrophe theory

Catastrophe theory is an approach that originated in the works of the French mathematician René Thom (e.g. 1981). Although it makes use of mathematical concepts and of a mathematical formalism, it is, strictly speaking, not a mathematical or scientific theory. Instead, "it is above all a method and a language. As any language, it serves to *describe* reality" (43, emphasis added). Whether the description is adequate or true is not guaranteed by the theory. The theory provides a way of describing the morphology of a system and the changes therein. That is, it is a tool for describing the connection between continuous changes, on the one hand, and the emergence of new forms (morphogenesis), on the other. Readers familiar with materialist dialectics will immediately recognize that catastrophe theory encapsulates one of the three dialectical laws: the law of the transition of quantity into quality and vice versa (Marx & Engels, 1975).

We may describe human growth in terms of a movement through a landscape resulting from the relation of two manifestations of a system, such as personal and environmental characteristics in the growth of a person or, alternatively, biological and cultural dimensions as they relate in the course of a child's life (Figure 2). Some of the trajectory involves continuous change (e.g., Figure 2, a, c, & e). But there are also instances of qualitative change (Figure 2, b & d). Both points are denoted as catastrophe. The first point corresponds to the

creation of a new form of behavior (function), which becomes possible (Figure 2, b) even though right up to immediately before it (i.e., in its "vicinity") such a creation remains unforeseen. When the system continues, the new behavior (function) is present as possibility; but it does not constitute the dominant form. At some point, minor variations in personal or environmental characteristics are such that they "precipitate" a changeover where the existing but minor behavior (function) becomes the dominant one (Figure 2, d), entailing a change in the form and content of the growth that ensues (Figure 2, e).

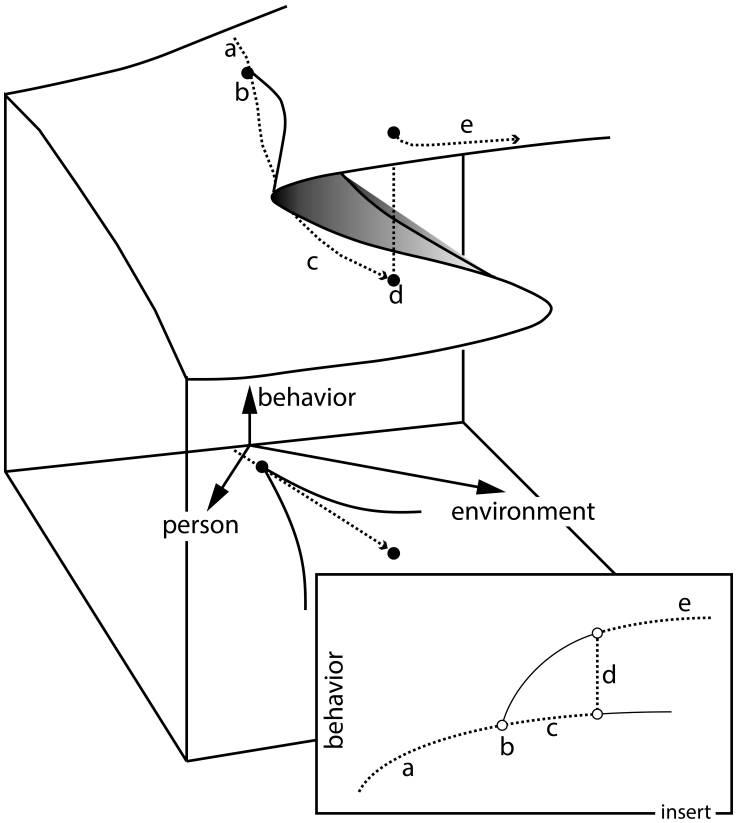

Figure 2. Depiction of the cusp catastrophe exemplified for a {person | environment} system. The insert follows the system's path highlighting the genesis of a new system function (behavior) at the first catastrophe "b" and a sudden transition at the second catastrophe "d," where the heretofore minor behavior becomes the dominant one, whereas the previously dominant one comes to subsist as a possibility in the background.

This catastrophe theoretic model for the emergence of new forms—i.e., morphogenesis—has been used to provide an account for an alternative model of evolution. In it, the phenotype of a particular organism is thought in terms of a ball rolling along the valley bottom of a complex (epigenetic) landscape (Figure 3). The system here is denoted as {genotype | (epigenetic) environment}.

Whereas there are two stable states within the fold for the first case of a system (Figure 2, branches c and e), the second example (Figure 3) has four valleys at the very front of the depiction. We see that these valleys have formed as part of the evolution of the system (from the back to the front). The system tends to be relatively stable at the valley floor. However, variations at either pole of the {genotype | (genetic) environment} system can push it into another valley—corresponding to the qualitative change in Figure 2, d. The particular model, known as the cusp catastrophe, also is useful for classifying the kinds of empirical observations contained in the two vignettes.

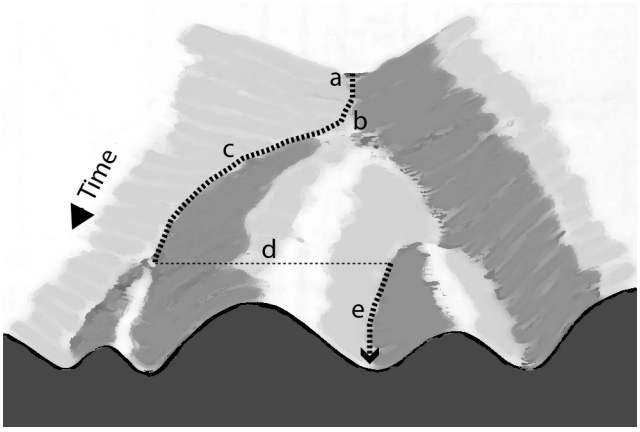

Figure 3. Trajectory of a {genotype | (genetic) environment} system in its epigenetic landscape. Variations anywhere in the system can flip it (horizontally) from one into another valley and, therefore, from one growth trajectory into another with very different phenotypic expression.

In the first case, we observe a student (Aslam) who, in the course of the relation with the investigator, changes the dominant form of responding to balance beam tasks from an additive strategy to a multiplicative (ratio and proportion) strategy. Although a certain level of biological development is the condition for such a change, the behavior is a typically human one and, therefore, understandable as a qualitative change in behavioral terms. For the particular case, we do not have available historical information and, therefore, do not know the extent to which Aslam already described phenomena in terms of doubling, tripling, and so on in other situations of his life. However, it is certain that he has had experiences in mathematics that deal with the relations between numbers. We may therefore assume that he already is familiar with such (mathematical) practices but, in the early part of the clinical interview, did not employ them to deal with the balance beam task. There are two aspects that have not been addressed or theoretically captured in the Piagetian literature: (a) the change in the task that the interviewer

sets up and (b) the existence of a social relation, existing in and produced by the joint labor. That is, without requiring any biological maturation, we observe a relatively quick transition (occurring over the course of a few verbal exchanges) to the use of a new way of dealing with balance beam tasks. Over time, this new form also includes more complex problems that Aslam does not initially solve, initially falling back on the additive approach before seeking a way to expand ratio reasoning.

In the second case, Leandro, we observe a rather sudden creation of a new form of consciousness concerning teaching and the changeover to the new way of understanding his reality of teaching. This changeover then provided a way of preparing lessons in a new way, so that, over a period of incremental changes, Leandro increasingly made his planning and implementation of lessons consistent with the new form of consciousness. In this case, the time between the emergence of a new form of consciousness and its becoming the dominant form was relative brief, occurring over the course of one (six-hour) long discussion that lasted until late into the night. If the duration of that meeting were plotted against Leandro's entire teaching experience, it would appear to have occurred instantaneously, even though it had its own temporality. As before, there were personal and environmental characteristics involved. Both the journal article and the discussion with his fellow inquirers are environmental characteristics that are associated with the emergence and amplification of dissatisfaction Leandro experienced with his then-current form of teaching. It was after a second reading of the "Poop" article, apparently occurring during that long evening, that a feeling emerged that he had received a double slap in the face, and the simultaneously articulated rejection of his earlier teaching methods.

Catastrophe theory only provides a way of classifying morphogenetic processes and events. It does not provide (social) psychologists, educators, or learning scientists with principles of method that direct researchers to search for and describe necessary and sufficient evidence for the transformation of quantity into quality. Whereas the catastrophe-theoretic description (Figure 2) makes apparent what is required—i.e., evidence for the five distinct parts in the growth trajectory of behavior—it was precisely K. Holzkamp who outlined in the *Grundlegung* a set of necessary and sufficient forms of evidence that would accomplish such a task.

Evidence for qualitative leaps in psycho-phylogenesis: A problem of method

In my reading, it was chapter 2 of *Grundlegung der Psychologie* (Holzkamp, 1983) that became a major point of interest. The chapter has the long, explicative title "The genetic base form of the psychic and its evolutionary formation; the methodical problem of providing evidence for qualitative leaps in psycho-phylogenesis." Here, the author takes up Leont'ev's (1981) reconstruction of the psyche from its beginning, thereby providing an account that is plausible on evolutionary and cultural-historical grounds, rather than beginning with psychological capacities that could not have given rise to thinking because they did not exist and there was no reason for them to emerge. For example, in constructivist accounts, the existence of the tools of construction tends to be taken for granted, rather than explained on evolutionary grounds. Piaget (1970) believes to have demonstrated that there are "three mathematical mother structures [that] have natural roots in the development of thinking in individuals" (p. 33). If one accepts the challenge of reconstructing the psyche in general and aspects thereof in particular, the problem of morphogenesis poses itself: how do *qualitatively new* forms of the psyche arise, that is, forms that are not yet contained or implied in the current makeup of the psyche? When and how did those psychological tools Piaget was wrote about emerge in the course of the history of the species, which continued into a cultural history following anthropogenesis? These qualitative changeovers include, most dramatically, the transition of *Homo sapiens* from a situation that might have been similar to today's primates to one in which society and its culture became the dominant, determining aspects in the life activity of the species.

To be able to observe evolution and development, the system of interest has to be such that there is an *inner contradiction*, as per the second of three main laws underlying the history of nature and human society: "the law of the interpenetration of opposites" (Marx & Engels, 1975: 348). Retracing the origin of "sensibility," Holzkamp (1983) outlines a natural history of the most elementary form of anything of psychological [psychische] nature. Sensibility is the determinant and determining function of organismic life; its emergence therefore marks the arrival of a stage where the psyche first exists in its most rudimentary form. In the course of evolution, the psyche evolves until its current human form emerges in, and is constitutive of, anthropogenesis. This concrete investigation of the necessary condition for the morphogenesis of the psyche in its most rudimentary form leads into the articulation of a methodical precept. Holzkamp here is true to the *materialist* dialectical precept that the laws of nature and history have to be derived from their study (Marx & Engels, 1975). This

approach is opposed to what can be frequently observed (by Vygotsky, 1997a, with respect to the law of the transformation of quantity into quality), where laws (theories) come to be imposed on a phenomenon of interest with the result that something is said to work in theory, but fails to work in practice. Whereas Engels asserts that the law of the transformation of quantity and quality "stands the test every step of the way in biology as in the history of human society" (p. 353), he does not actually provide detailed examples. Rather, he concentrates on the "exact sciences" (i.e., physics, chemistry, and mathematics), because in these fields, quantities can be observed more and measured more exactly. It would be up to Leont'ev (1981) and Holzkamp (1983) to provide a plausible description of morphogenesis in biology. Holzkamp, based on the analysis of the sequence of levels in the appearance of the psyche, thus makes a "methodical [methodische]" turn by specifying five analytic steps required to provide evidence for the transformation [Umschlag] of quantity into quality. It is an attempt to provide "*a methodical concretization of the basic dialectical law of the 'transformation of quantity into quality' for our field of inquiry* [Gegenstandsbereich]" (Holzkamp, 1983: 78). Holzkamp shows how those five steps in the changeover from quantitative to qualitative change pan out in phylogenesis. My own interest lies in *human* learning and development, which is why I draw on the preceding examples from personal development.

In a first step, the investigator has to provide a description of the *real-historical dimensions* of the level that precedes the qualitative change and that constitutes the ground upon, and material with which, the qualitative change occurs. The investigation does not have to articulate "everything" about the life of the organism (person) but only those aspects that are "*dialectically 'negated'* in the qualitative transformation [Umschlag]" (Holzkamp, 1983: 79). The precise nature of the transformation in morphogenesis therefore comes to be highlighted in the integrality of its specificity. In the epigenetic landscape, this part of the investigation concerns the trajectory of the system prior to a bifurcation point (Figure 2 & 3, a). In the two sets of case material, this step corresponds to describing forms of behavior preceding the change to a new psychological form. In the first of my two cases, the investigation starts with the clinical interview from which the materials were taken. At this stage, Aslam would have likely exhibited some forms of proportional reasoning elsewhere in his life, after first having encountered them through in family relations or in some of his classes. Without having further evidence, we most likely will have found ourselves prior to the second qualitative leap (Figure 2, c), which itself occurs during the interview. As the study unfolds, it becomes clear that, from this, a qualitatively new behavior becomes the dominant one (i.e., proportional and multiplicative reasoning), further differentiating itself with respect to task difficulty and with

type of task—e.g., "transferred" to other forms of levers, such as class II levers (wheelbarrow) and class III levers (e.g., baseball bat, shovel). In the case of Leandro, the doctoral student collecting the data has had many exchanges with him and interviewed him on many occasions, producing a detailed picture of his growth as a teacher. In all of these accounts, and even though Leandro had been familiar with the work of Paolo Freire, these relations were not standing out in his conscious awareness: the possibility of the contradiction between his teaching and what students actually learned, the contradiction between his view of learning and the curricular plans, and the possible irrelevance of what students learned in school to their everyday lives.

In a second step, the investigation has to provide evidence for the objective changes at the environmental pole of the {person | environment} system that lie at the origin of the inner contradictions that eventually lead to the genesis of a new psychological form. For this, it is important to trace two aspects of the environment. For one, the investigation has to articulate those environmental features that "threaten" or put pressure on the system that provides a particular force in the direction of the change that eventually occurs. Furthermore, the investigation has to articulate those environmental features that will be relevant to the new form. In the case of studies such as the one involving Aslam, investigators have to show when and where a new behavior (function) emerges. In the case of Leandro, the researcher is actually present when this occurs. The occasion is a particular article read and discussed by the participants. As Leandro describes afterwards, his first reading gave rise to a sense of dissatisfaction with his own teaching. That is, in the reading, the teaching of another teacher comes to be held against his own teaching. But this does not mean that the materials themselves provoked such a change of appreciation. Another participant, even though her teaching is also characterized by traditional methods, sees herself only confirmed by the "Poop" story, leading her to assert that she is already acting similarly to the teacher in the article. Leandro's initial dissatisfaction is amplified and becomes differentiated during a second reading on the night of the discussion. It is here that he articulates the dual contradiction of having set up conditions that contribute to the failing of (some of the) students in school examinations, and of having failed students for a second time in neglecting the effect of school on students' developmental trajectory in life as a whole (i.e., relevance of school learning to life). In terms of the above-described model, this part of the investigation pertains to changes that occur on the trajectory just prior to what will constitute a bifurcation.

In the third step, a functional change has to be documented in "the relevant dimension of the *'organism pole' of the developmental contradiction*" (Holzkamp, 1983: 79). This functional change constitutes a first qualitative leap

of the specific form of the new function in the context of the changed environment. It makes available a qualitatively new behavioral form, which is the form that eventually becomes the dominant one. In the epigenetic landscape, this step corresponds to a point of bifurcation where a new function becomes available (Figure 3, b). The bifurcation point is interesting because it belongs to two regimes. Approaching it from one side, there is only one form of behavior (function), whereas going backward in time the point corresponds to two forms of behavior (functions). Holzkamp makes the important point that the dialectical negation occurs only in a minor or partial function that is still subordinated to the main function of the earlier level. Thus, for example, in the first case study above, Aslam already exhibits reasoning in terms of proportions, but he does manifest it in the context of the balance beam task, which in fact requires the comparison of two proportions. At this stage, the proportionality form is still subordinate to the additive form of reasoning. Other studies of mathematical reasoning in early elementary school show how new forms of reasoning first appear in the lives of children in their relations with teachers (e.g., Roth, 2016). The pertinence of this instant in time is not salient; it does become so only when the new behavior has become the dominant one. At that point, backtracking of signs leads to the point in time where there is a first sign of the behavior in the life of a particular child. This instant marks a *growth point*, where there is both an immediate departure from the context conditioned by the same context (e.g., McNeill, 2002). In fact, the study shows consistent with Vygotsky (1989) that what will subsequently have been an individual behavior (psychological function) first *was* a social relation with the teacher. In the second set of case materials outlined above, when Leandro becomes conscious of a dual contradiction, he still continues based on the teaching methods he knows, while trying out a new method at the same time. The new way of teaching is still subordinate to the old ways that have constituted the grounds for the subsequent reversal. His consciousness operates at two levels: at the time, he still plans some lessons in the old way, from his old perspective, and also plans some lessons in a new way, overcoming the contradictions within his old ways. Over time, the proportion between these two ways changes. The new ways still are not determining and determinant for the total Leandro-teaching-in-the-school system.

As a fourth step in the investigation, the researcher provides evidence for a change in the dominant, system-determining form of behavior (function). This change in dominance constitutes a *second qualitative leap*, whereby the heretofore-minor function becomes the major one, while simultaneously the major function is pushed into the background. That is, the function (behavior) does not disappear altogether. This point is often forgotten in descriptions of conceptual change from naïve to scientific conceptions, where it is assumed that

the new conception (discourse) is paralleled by an eradication of the old conception (discourse). This does not account for the actual observation that scientists may continue to talk about everyday phenomena, such as the sun, in ways that are consistent with an Aristotelian worldview, according to which the sun moves across the sky and around the earth (e.g., "what a beautiful sun*rise*). Holzkamp makes a point that is consistent with the above-described biological picture of evolution. Accordingly, new life-determining (dominant) functions are not spontaneously created in response to some contradiction arising in the niche. Instead, "*new organismic functions* ... always form *gradually from almost unnoticeable beginnings*" (Holzkamp, 1983: 80), which entails that it *cannot* be the determinant function. Instead, the system continues on what has been a stable path. When the qualitative leap occurs nevertheless, it is because there is a reversal of two dimensions, each of which undergoes continuous (i.e., quantitative) change. Even though the two dimensions of the {person | environment} system change continuously, the changeover in dominance occurs (almost) instantaneously. This changeover is represented in the articulation of the catastrophe theoretic approach (Figure 2, d) and in the changeover between two phenotypes of the same organism (Figure 3, d). In both sets of case materials, evidence for this step exists. A detailed, instant-to-instant microanalytic case study would exhibit that turnover. Once the dominance of the new behavior is apparent, backtracking allows specification of the precise social and material conditions that provided the ground for the reversal in dominance. In the case of Aslam, for example, the immediate events includes a physical rotation of the balance beam, so that the distance markers are no longer seen and an eventual return to the task by asking about the distance of the smaller weight given the distance of the larger one from the fulcrum. The change itself can be traced back to the give-and-take relation involving the clinical interviewer and Aslam and, thus, to what will have been the endpoint a {query | reply} sequence ending in the articulation of the ratio and multiplicative rules that then dominates in subsequent tasks. This example also shows that Vygotsky wrote quite appropriately about a *zone of proximal development*, where the second part really pertains to a *qualitative* change rather than merely an accumulation of cases within an existing form of experience (behavior) (see also below).

In step five, the investigation provides evidence for the restructuring that the system has undergone and for the new developmental direction of the system as a whole, given the dominance of a new behavior (function) over the subordinated older behavior (function). This part of the investigation, corresponding to the growth trajectory following the qualitative leap to a new dominant behavior (function) (Figure 2, e), requires articulating (a) those dimensions that no longer have a main function in the system and (b) how older

dimensions take on new functions. As described above, Aslam does use the proportional reasoning on balance beam problems, and refines the forms of reasoning with increasing task complexity. He also begins to "transfer" this form of reasoning to tasks concerning other types of simple machines. It also has to be shown how specific, structural and functional differentiations occur as the {person | environment} system continues on its developmental path. Some of the qualitatively new behaviors (functions) may actually be subordinated to a dominant form, that is, they become new forms of behavior without being the system-determining function. This continuing differentiation is clearly visible in the model of the epigenetic landscape, where there are multiple phenotypic expressions that evolve without ever having to become the principal, all subordinating one.

Discussion

The purpose of this paper is to present an important legacy of the *Grundlegung der Psychologie* that is not frequently, if at all, taken up: the necessary and sufficient elements of a description that shows the transition of quantity into quality (and vice versa) in psychological phenomena. The point, however, is not to foist any dialectical principles or method onto phenomena, but to identify any dialectical principle in the phenomena themselves. This echoes Engel's advice that Vygotsky (1979a) also adopted, and which is clearly operational in the way in which Holzkamp extracted the methodical principles from the summary of the work Leont'ev (1981) had done concerning the emergence of sensibility. The present study also shows how the changeover from quantity into quality in psychology, as per the *Grundlegung*, is part of a set of general phenomena in the natural sciences, social sciences, and humanities classified by means of catastrophe theory.

In the presentation of the method-related principles, I show how it maps onto the classificatory scheme. The comparison highlights that the first three steps of the method map onto the first two parts of the classification (Figure 2, a & b). The fourth step of the method concerns the evidence for a qualitative leap: a changeover of the dominance of one behavior (function) and the subordinate nature of a second behavior (function) in the life processes of the person (Figure 2, d). The fifth step in the method corresponds to the growth trajectory following the qualitative leap, which is different from the trajectory before the appearance of the new behavior (function) because the coming of the latter has led to a psychological reorganization. Holzkamp already notes that there is an intermediate step between (a) the first qualitative leap (i.e., emergence and

appearance of a new behavior or function) and (b) the second qualitative leap (i.e., change in dominance from the "negated" behavior or function). Research in very different domains and concerning very different phenomena exhibits the sometimes quite extended period during which both behaviors (functions) may be equally salient. For example, in a scientific research group, in the process of providing evidence for a particular theory that previously had led its founder to receive a Nobel Prize, the suspicion arose that the theory is inappropriate (Roth, 2014). It took nearly two years of data collection, during which the team sometimes explained data in terms of the old theory and sometimes explained data in terms of an alternate approach, before they replaced in their discussions the old, Nobel Prize winning theory with a new one in their discussions. Similarly, in the research on gestures that accompany speech, it is well known that children explain mathematical phenomena verbally in ways consistent with one concept, all the while using gestures that are consistent with another, more advanced concept (e.g., Alibali & Goldin-Meadow, 1993; Church & Goldin-Meadow, 1986). In fact, when children are followed over longer periods of time, one observes that their gestures and words initially agree in expressing a particular concept, then begin to disagree with the gestures generally exhibiting the new, more advanced concept, before words "catch up" and, together with the gestures, also express the more advanced concept.

The qualitative leap is of particular interest in the case exemplified by Leandro's story, because it shows how critical consciousness (*conscientização*) may arise when it does not yet exist in the experience of a person and yet, after the fact, arises unforeseeably in its own absence. This aspect is especially relevant in the context of schooling, where teachers are enabled to set up conditions that may lead to the emergence of critical consciousness on the part of their students. The methodical precepts articulated in the *Grundlegung* provide us with the means for studying the precise circumstances of the when, where, and how of the phenomenon.

Actual studies referred to above show that the qualitative changeover, therefore, is not as instantaneous. The research in the gesture domain generally is of what Holzkamp (1983) calls "variable psychology," an approach that is little suited to show the actual sequence of events in which new behaviors (psychological functions) emerge, the conditions and contradictions that lie at their origins, the growth trajectory that ensues, and the instant when the ultimate changeover occurs to the more advanced behavior (function). My own research shows, however, that microanalyses of human interaction at the sub-second level are ideally suited to document the morphogenesis of new behaviors (psychological functions) in joint labor (e.g., Roth, 2016). Such work furthermore shows that psychological development essentially occurs as

sociogenesis, rather than being reducible to biological maturation and spontaneous emergence of specifically human (cultural) behaviors.

In the description of the five-step method, Holzkamp (1983) draws on the discourse of dialectics. He notes, for example, that part of the method's first step is the "determination of exactly that '*position'* that is *dialectically 'negated*' during the qualitative leap" (p. 79). We note that the verb negate is enclosed by quotation marks. Actual observations of psychological growth processes show that behaviors and functions are not "negated" in any simple sense. Instead they become part of the sediment upon which the qualitatively new forms appear. For example, additive forms of reasoning continue to be available to Aslam as shown during the entire physics unit that follows the clinical interview. What has changed is the fact that in the context of particular tasks, he does no longer employ it. That is, the additive form of reasoning is alive and well. There is therefore not a simple opposition of lower and higher function. Not surprisingly, near the end of his life, Vygotsky recognized in his own previous work an inherent dualism concerning the two-tiered nature of the higher and lower functions (Zavershneva, 2010). He began reading Spinoza through a Marxian lens, a viewpoint that emphasizes the plurality of manifestations and parts of Nature. Such a lens allows us to better capture the events that happen along the growth trajectory corresponding the emergence of a first qualitative leap (first catastrophe) (Figure 2, a & b).

When we observe some psychological {person | environment} system, particular forms of behavior (practical action, intellect, affect) are documented prior to what will have been a period during which a new behavior (function) establishes itself. Afterwards, we still see the system as a whole, though it is now restructured such that person and environment characteristics in/of performance differ. At the instant of time when a new behavior (function) becomes a reality in the life of the person, a new way of being is possible and eventually becomes salient. But that new way is simply a different manifestation of life, not a negation thereof. As the image of the epigenetic landscape suggests, there is differentiation without disappearance, and under certain conditions, the trajectory is continued on a different, perhaps more viable, useful, or successful path (Figure 3). The figure better expresses a Spinozist Marxian take on morphogenesis and the relation between the different behaviors (functions) than a Hegelian approach to materialist dialectics.

In everyday use, the concepts "learning" and "development" frequently are not clearly distinguished. Thus, we may read about how "learning is all about making employees knowledgeable while development is concerned with making employees incorporate new skills into their behavior as habits" (Difference Between, 2012). In the research literature, such as that concerning the

"professional development" of teachers, incremental (quantitative) growth tends to be subsumed to the term that might suitably be employed to distinguish periods in which qualitative leaps to entirely new forms of behavior occur. Thus, "new skills" are not inherently qualitatively new, such as what occurs when a sequence of several actions comes to be habitually linked and thus becomes one action. The linking of all parts of manually changing gears of a car is the result of coordinating already existing competencies, not the emergence of a completely new competency. The method Holzkamp proposed is useful in this context, for it forces researchers to articulate the qualitatively new, when it arises, and at what point and how it becomes the dominant behavior (function). Importantly, as the catastrophe-theoretical formulation makes apparent, the new behavior (function) is unforeseen from within the system as it nears the bifurcation point. That articulation also suggests that the variations may occur anywhere in the system, because variations both in personal or environmental characteristics can precipitate the emergence of a new behavior (function). Detailed case studies of concrete situations will reveal when and how such bifurcations occur.

One important psychological concept is that of *zone of proximal development*, which is defined by the difference between the developmental level of an individual's actual performance and that level observed in joint work with another person (Vygotsky, 1987). We may conceive of this concept in terms of the systemic category {person | environment}, where the environment has both material (physical) and social dimensions (Figure 4). The system under consideration, therefore, includes not only the person under investigation (e.g., a child in school or the psychological laboratory), but also the others with whom the person is in relation. In that relation, the other person also changes, and so do the relations of both with the environment and with the other.

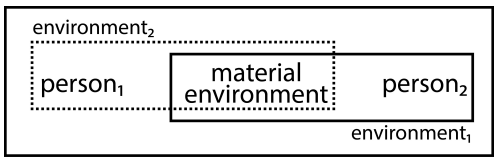

Figure 4. The system under consideration in developmental studies; no part can be considered independent of any other part.

Once we conceive our system in this way, it is apparent that the very presence of the adult may, but does not have to, create a situation equivalent to the fold (Figure 2). It corresponds to a variation in the environmental characteristic. In that case then, the vertical distance between the two surfaces on which the system may move corresponds to (is a literal expression of) the zone of proximal

development. The method articulated above provides us with directions for showing when and how what will have been a qualitatively new form of behavior (psychological function) first appeared, how by interacting with others or working on its own the child behaves until a qualitative leap will have been observed. That is, the method provides us with a way of conducting and documenting the sociogenesis of new psychological functions and behaviors. Vygotsky was actually cautious in articulating development in a retrospective manner, stating, in following Marx, that "any higher psychological function … *was* social; before becoming a function, it was the social relation between two people" (Vygotsky, 1989: 56). That is, not every relation between two people leads to a new function, but every new function can be traced back to the relation between people.

The *Grundlegung* therefore provides us with the precepts for studying developmental phenomena anthropologically by investigating situations in which those under study (children, students, adults) engage in joint labor with others. In backtracking efforts for the purpose of identifying a growth point—corresponding to the first catastrophe (Figure 2, b) or the first qualitative leap—it may be useful and fruitful to follow an approach in gesture studies where the notion of *catchment* has currency (McNeill, 2002). A catchment is defined as a recurrent feature in two or more not necessarily consecutive gestures; it therefore is what has been named a *tracer* (Newman, Griffin, & Cole, 1989), a feature in a psychological phenomenon that marks its reoccurrence across situations and context. Because gestures in particular may express something different from words, we may backtrack the two forms of expression to the point where psychologically divergent forms first appear. We may then study more closely the conditions that will have constituted the coincidence of two developmental periods, the end of one and beginning of another. The catchment (tracer) approach fills in an area in developmental studies that the *Grundlegung* did not explicitly address.

Taking the approach described here will reveal in many, and, if Vygotsky is right, in all cases of backtracking what appear to be spontaneous forms of development are actually social phenomena, forms of sociogenesis. It then will no longer be mysterious why a 20-year-old African American college student is reading very much like a three-year-old child—as this appeared in story about Desmond Cathey published in *The Chronicle of Higher Education* (Wolverton, n.d). In the story, Desmond, though in college, was tracking letters with a finger tracking below them, putting together words one sound at a time. In another story found online, a three-year old apparently reading on her own with a few corrections and little assistance by a parent (Roth & Jornet, 2017). The article about Desmond Cathey reveals that he grew up in poverty to parents living on

social assistance. If we were able to turn the clock back to see the boy, then the social relations would have been different from those of the three-year-old girl that was already reading. In this manner, for example, the ways of doing mathematics often observed among girls in schools could be traced back to the kinds of relations working-class have at home with their mothers, relating to the daily chores typically accomplished in working class families by women rather than by men (Walkerdine, 1988).

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Wolff-Michael Roth is Lansdowne Professor of Applied Cognitive Science in the Faculty of Education at the University of Victoria, Canada. His trans-disciplinary and trans-method research investigates knowing and learning across the life span in formal educational, workplace, and leisure settings.